RESPIRATORY AIR SUPPLY SYSTEM WITH AIRFLOW DEPENDENT HUMIDITY

This invention relates to respiratory air supply systems incorporating humidification. In particular it relates to a system where the humidity and/or temperature of the air supplied is a function of the air flow passing through the system.

An external air supply may be necessary to assist a patient's breathing in a variety of circumstances. Different devices may be used to provide a positive flow of air. For air supplied to a patient's mouth or throat a ventilator may be used. For air supplied nasally a continuous positive airway pressure (CPAP) blower may be used. In both cases, it is often desirable that the air supplied is humidified, although the reasons for so doing may differ.

It has been discovered that there are advantages in controlling the humidity of air supplied nasally in accordance with variation of flow rates and/or nasal airway resistance (NAR). Furthermore it has been discovered that mouth leaks induce NAR, but that an adjustment to humidity on detection of a mouth leak may prevent or reduce the incidence of NAR. A typical situation is in the use of nasal CPAP (nCPAP) in the treatment of obstructive sleep apnoea patients.

It is therefore an object of the present invention to provide a respiratory air supply system which implements the above discovery.

Accordingly, in one aspect the invention consists in a method of supplying respiratory air to a patient including the steps of:

humidifying the air supplied to the patient,

sensing the flow of said air to detect changes in patient airway resistance, and

controlling the humidity and/or temperature of said air by increasing the humidity and/or temperature when an increase in airway resistance is detected and decreasing the humidity and/or temperature when a decrease in airway resistance is detected.

In a further aspect the invention consists in apparatus for supplying a patient with humidified respiratory air comprising:

air humidifying means which humidifies air supplied from an external source to a controllable humidity and temperature,

an electronic controller for said humidifying means which determines the humidity and temperature of air leaving said humidifying means, said controller having inputs to receive signals indicative of patient airway resistance,

a respiratory face mask for application to said patient,

an air supply tube coupling the output of said humidifying means to said face mask, and

an airflow transducer which monitors flow in said air hose, the output of which is connected to at least one said controller input,

the controller configured to increase the humidity of air leaving the humidifying means when said air flow transducer indicates an increase in patient airway resistance and to decrease the humidity of air leaving the humidifying means when said air flow transducer indicates a decrease in patient airway resistance.

One embodiment of the present invention will now be described with reference to the accompanying drawings in which:

Figure 1 shows a respiratory air supply system in diagrammatic form,

Figure 2 shows the humidifier controller electrical circuit, and

Figures 3A and 3B show the controller algorithm in flow diagram form.

The present invention will be described with reference to its use in providing a nasal air supply for patients suffering obstructive sleep apnoea. Referring to Figure 1, a source of air, in this case a nasal continuous postive airway pressure (nCPAP) blower (not shown) supplies air to tube 1 which is connected to the inlet 2 of a humidifying chamber 3. Chamber 3 contains water which is vaporised by a heated base 4. Air enters the chamber through inlet 2 and leaves through outlet 5 entraining water vapour as it does so. A connector 6 couples the outlet 5 to tube 7 which carries the humidified air to a patient face mask 8.

Referring also to Figure 2, the humidifying chamber 3 base 4 is heated by an electric element 16 mounted in the top of a humidifier controller 9 and the energy supplied to the heating element is determined by certain preset variables and a number of feedback inputs. Typically, there may be two feedback signals

representative of air temperature at the outlet of the humidifier 5 (T_2) and air temperature at the patient end of tube 7 (T_1). This temperature feedback does not however comprise part of the present invention.

In addition to controlling the heat supplied to the humidifier chamber 3, controller 9 also supplies current to a heating wire 17 associated with tube 7 via electrical connection 10. Tube 7 is heated so as to prevent or reduce condensation of the humidified air as it passes through the tube to the patient.

Connector 11 which terminates tube 7 and which couples the airway to face mask 8 may incorporate a calibrated orifice (not shown) and two pressure transducers 12 and 13 located either side of the orifice. Signals representative of the measured pressures P_1 and P_2 are provided by pressure transducers 12 and 13 respectively and applied as inputs 14 and 15 to controller 9. The pressure difference $P_1 - P_2$, together with the calibrated orifice, enable controller 9 to calculate the flowrate of air being delivered to the patient through tube 7. Controller 9, which typically incorporates a programmed microprocessor 18, is programmed to control heater 16 to vary the humidity and/or temperature of the air entering tube 7 from a base value of humidity as a function of the measured air flow rate. The microprocessor produces display information which is fed to display 20 via a display driver 19. An alarm 21 can be actuated by the controller when monitored variables exceed predetermined limits.

Figure 2 shows other inputs 22 to the controller, but these do not form part of the present invention.

A reduction in airflow indicates nasal airway resistance (NAR) which may be due to inflammation and the controller causes the humidity of the air entering tube 7 and thus leaving tube 7 to be increased. This helps reduce the inflammation and assists in reducing NAR. Similarly, excessive air leakage

through the mouth may induce an increase in NAR. However such leakage will cause an increase in air flow which increase can be detected and controller 9 increases the humidity of the air supplied to the patient which will tend to forestall any subsequent increase in NAR. If any reduction in NAR is sensed humidity will be decreased, although it will not reduce below a preset base value.

The algorithm implemented by microprocessor 18 is shown in Figures 3A and 3B. The system is initialised in block 31 by setting the appropriate base values of flow, pressure, NAR and humidity (ambient and saturated). In block 32 a determination is made from measured flow whether a mouth leak exists. If not, the algorithm proceeds from block 37 where nasal airway resistance is tested. If a mouth leak is detected, the algorithm proceeds to level 33 where a test is made for change. In level 34 humidity of air supplied by the humidifier to the patient is tested to check whether it is already at a maximum or a minimum. The algorithm then proceeds to level 35 where a decision (and subsequent implementation) on increase or decrease of humidity is made. The sequence then pauses and loops back (36) to block 32. The algorithm for nasal airway resistance per se (Figure 33B) is the same as that described above.

Although the invention has been described with reference to using air flowrate as the primary feedback variable, the use of a single pressure transducer may be adequate with a pressure increase indicating increased NAR.

Furthermore other transducers for providing a signal indicative of flow could be used in place of the pressure transducer/calibrated orifice combination described above.

The source of air, for example a blower, need not be a separate item of apparatus from the humidifier as indicated above, but could be integrated with the humidifier to form a single unit. Alternatively, the humidifier controller may also control the blower without the need for a separate blower controller.

It will be appreciated from the above that the present invention can provide a respiratory air supply having a temperature and humidity which is optimum despite air flow leakage and/or changes in NAR.

CLAIMS

1. A method of supplying respiratory air to a patient including the steps of:

humidifying the air supplied to the patient,

sensing changes in the flow of said air, and

controlling the humidity and/or temperature of said air such that the humidity and/or temperature is increased from a preset base value when air flow decreases as a result of an increase in airway resistance or when air flow increases as a result of air leakage.

2. A method according to claim 1 wherein the air is supplied nasally to said patient and the airway resistance sensed is nasal airway resistance.

3. A method according to claim 2 wherein the operations of sensing air flow and controlling humidity are performed cyclically in accordance with a procedural sequence comprising:

(i) sensing air flow for an increase indicative of mouth leakage, and if detected causing humidity to be increased, but if no increase is detected;

(2) sensing air flow for a decrease indicative of increased nasal airway resistance, and if detected causing humidity to be increased.

4. Apparatus for supplying a patient with humidified respiratory air comprising:

air humidifying means which humidifies air supplied from an external source to a controllable humidity and temperature,

an electronic controller for said humidifying means which determines the humidity and temperature of air leaving said humidifying means, said controller having inputs to receive signals indicative of air flow,

a respiratory face mask for application to said patient,

an air supply tube coupling the output of said humidifying means to said face mask, and

an airflow transducer which monitors flow in said air hose, the output of which is connected to at least one said controller input,

the controller configured to increase the humidity of air leaving the humidifying means above a preset base value when said air flow transducer indicates a decrease

in air flow to the patient or when said air flow transducer indicates an increase in air flow to the patient

5. Apparatus according to claim 4 wherein said airflow transducer comprises a calibrated orifice in series with said air supply tube, a first pressure transducer located on the upstream side of said orifice, and a second pressure transducer located on the downstream side of said orifice, said first and second transducers each supplying signals to respective controller inputs, and said controller programmed to calculate air flow from the two pressure signals and the orifice parameters.

6. A method of supplying respiratory air to a patient substantially as hereinbefore described with reference to the accompanying drawings.

7. Apparatus for supplying a patient with humidified air substantially as hereinbefore described with reference to the accompanying drawings.

ABSTRACT

A patient respiratory apparatus which includes a humidifier having a controller which detects airway resistance and which increases the humidity of the air supplied to the patient when an increase in airway resistance is detected. The apparatus is particularly suited to nasal continuous positive airway pressure (nCPAP) where increases in nasal airway resistance, however arising, including increases induced by mouth leakage, are compensated by an increase in the humidity of the air supplied to the patient.

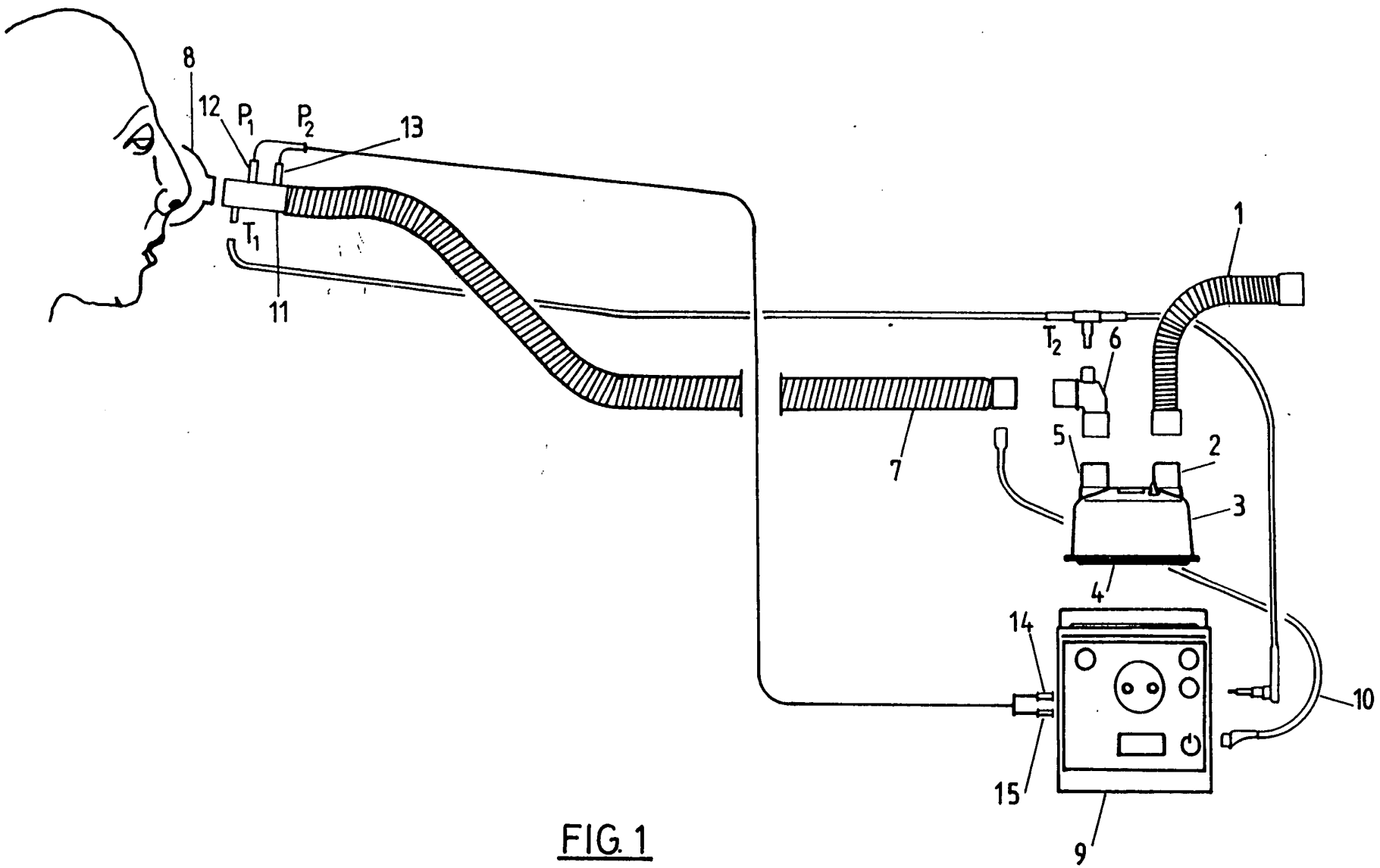
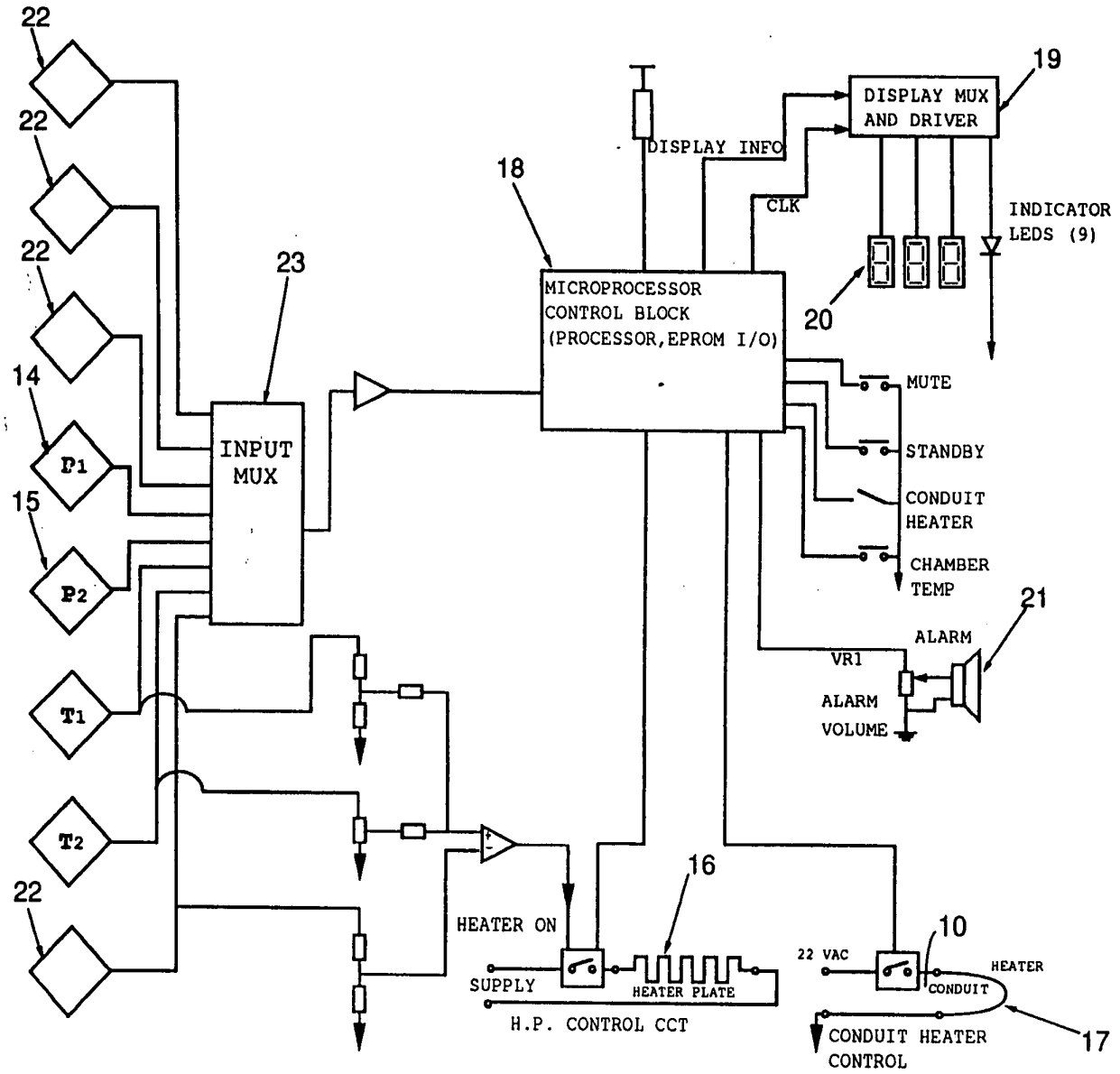


FIG. 1

FIG. 2


22
22
22
22
14
15
22
P1
P2
T1
T2
INPUT MUX
23
18
MICROPROCESSOR CONTROL BLOCK (PROCESSOR, EPROM I/O)
DISPLAY INFO
CLK
DISPLAY MUX AND DRIVER
19
INDICATOR LEDS (9)
20
MUTE
STANDBY
CONDUIT HEATER
CHAMBER TEMP
21
ALARM
VR1
ALARM VOLUME
16
HEATER ON
SUPPLY
HEATER PLATE
H.P. CONTROL CCT
10
22 VAC
HEATER
CONDUIT
CONDUIT HEATER CONTROL
17

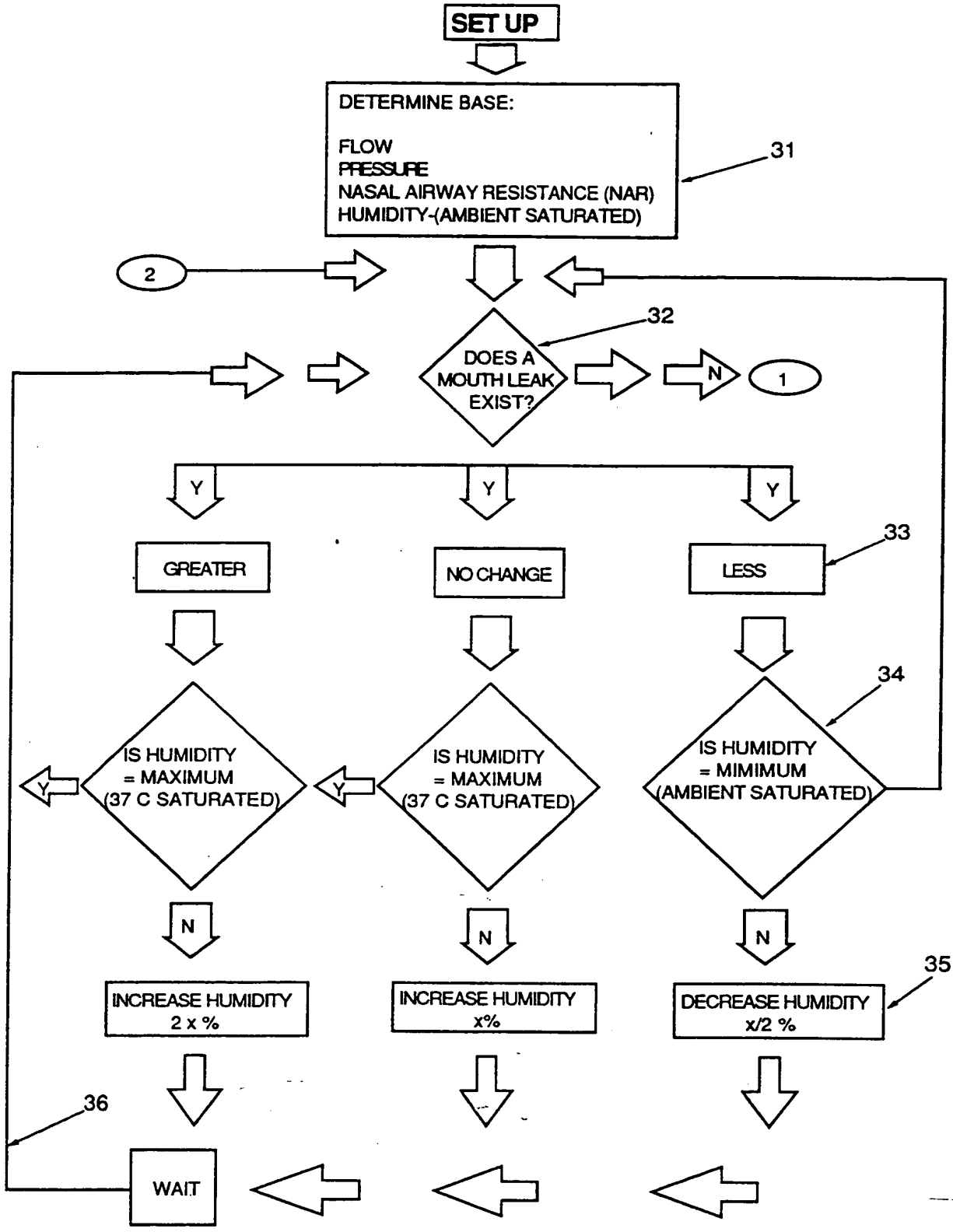

SET UP
DETERMINE BASE:
FLOW
PRESSURE
NASAL AIRWAY RESISTANCE (NAR)
HUMIDITY-(AMBIENT SATURATED)
31
2
32
DOES A MOUTH LEAK EXIST?
N
1
Y
Y
Y
GREATER
NO CHANGE
LESS
33
34
IS HUMIDITY = MAXIMUM (37 C SATURATED)
IS HUMIDITY = MAXIMUM (37 C SATURATED)
IS HUMIDITY = MIMIMUM (AMBIENT SATURATED)
Y
Y
N
N
N
INCREASE HUMIDITY 2 x %
INCREASE HUMIDITY x%
DECREASE HUMIDITY x/2 %
35
36
WAIT

FIG. 3A

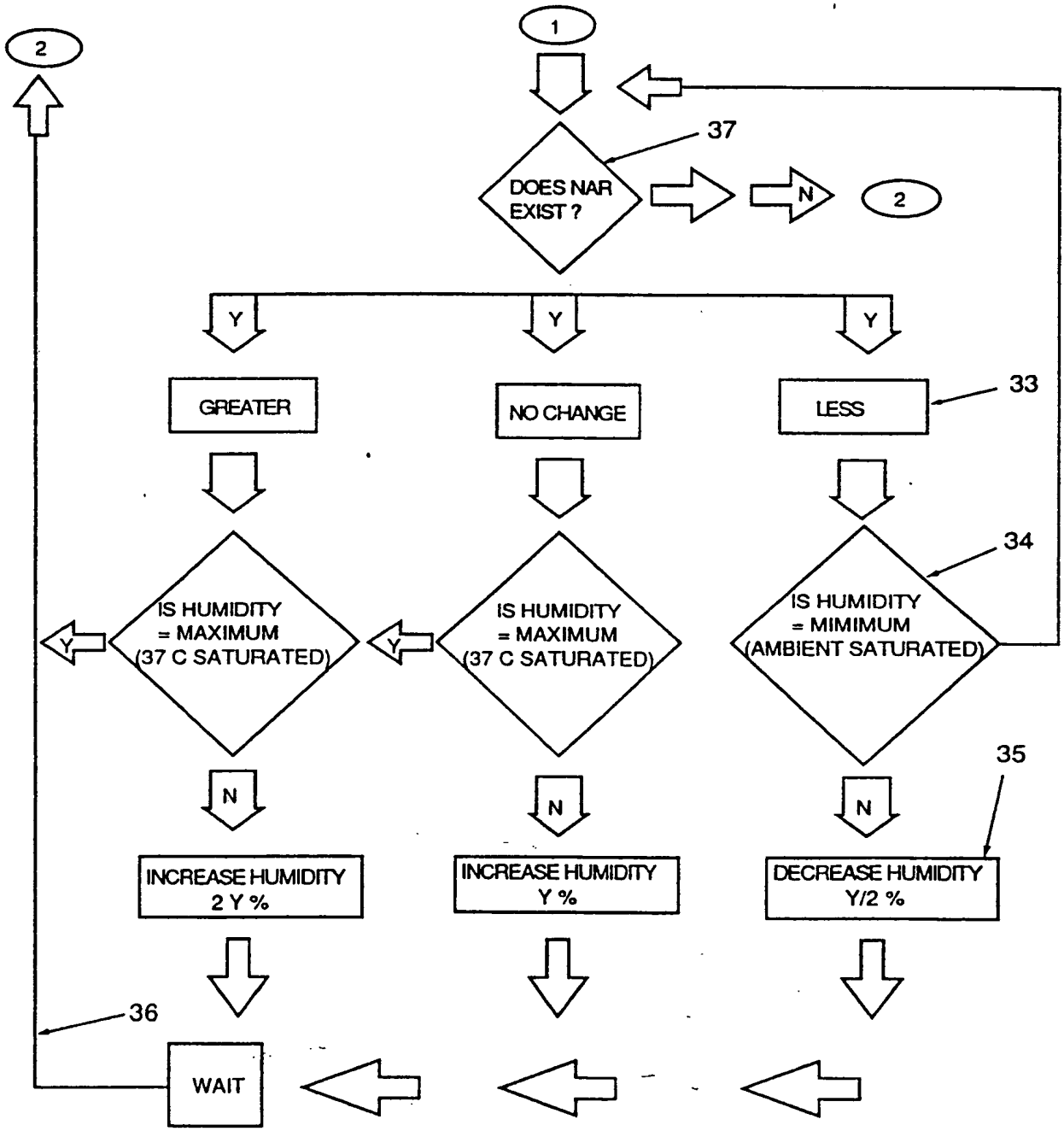

1
2
37
DOES NAR EXIST ?
N
2
Y
Y
Y
GREATER
NO CHANGE
LESS
33
34
IS HUMIDITY = MAXIMUM (37 C SATURATED)
IS HUMIDITY = MAXIMUM (37 C SATURATED)
IS HUMIDITY = MIMIMUM (AMBIENT SATURATED)
Y
Y
N
N
N
35
INCREASE HUMIDITY 2 Y %
INCREASE HUMIDITY Y %
DECREASE HUMIDITY Y/2 %
36
WAIT

FIG. 3B